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How motor experiences alter action perception: A computational account

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Behavioral studies suggest that self-experiences of actions facilitate infants' understanding of others' actions. Infants can recognize the goal-directedness of others' actions (Sommerville et al., 2005; Gerson & Woodward, 2014), predict the goals of observed actions (Kanakogi & Itakura, 2011; Myowa-Yamakoshi et al., 2012), and differentiate possible and impossible actions (Meltzoff & Brooks, 2008; Myowa-Yamakoshi et al., 2011) if they have previous experiences of producing targeted actions. Experiments using preferential looking paradigms also revealed a strong link between action perception and production in infants (e.g., Sanefuji et al., 2008; Hauf & Power, 2011). Infants developmentally shift their action preference as they improve their motor abilities.

To understand the underlying mechanism for this development, we propose a computational model of infant action learning. Our hypothesis is that infants learn to acquire a forward model (i.e., a predictor) based on their sensorimotor experiences and recognize others' actions using the predictor. Figure 1 depicts a conceptual model of the predictor combined with the sensorimotor system (Nagai & Asada, 2015). The predictor learns to simulate temporal sequences of sensorimotor signals by minimizing a prediction error. Infants' own experiences of generating actions are used to update the predictor. The predictor is then applied to recognize actions demonstrated by other individuals. Others' actions perceived as sensory signals are simulated by the predictor, which further induces corresponding motor signals. Of importance here is that the induced motor signals facilitate the prediction of sensory signals. As motor and sensory signals are closely integrated in the predictor, self-experiences of actions directly facilitate the understanding of others' actions.

We conducted a robotic experiment to verify our hypothesis (see Figure 2). Inspired by (Sommerville et al., 2005; Gerson & Woodward, 2014), a robot was examined in two conditions (Baraglia et al., 2015): In a self-experience condition, a robot first learned to produce reaching behaviors. A predictor modeled using a recurrent neural network was trained with sensorimotor signals obtained from the reaching experiences. The robot was then presented with others' actions reaching for an object. In a no-self-experience condition, a robot was not given a chance to learn to produce its own behaviors. The robot trained the predictor only based on sensory experiences obtained from the observation of others' actions. Our experiments verified our hypothesis: Only the robot in the self-experience condition could recognize others' actions as goal-directed. Furthermore, it could duplicate the attention behaviors of infants presented in (Sommerville et al., 2005; Gerson & Woodward, 2014). The robot in the self-experience condition increased its looking time when the goal of others' actions changed, whereas the robot in the no-self-experience condition did not show such an increase. Our computational model provides a great insight into how motor experiences of infants facilitate their perception of others' actions.

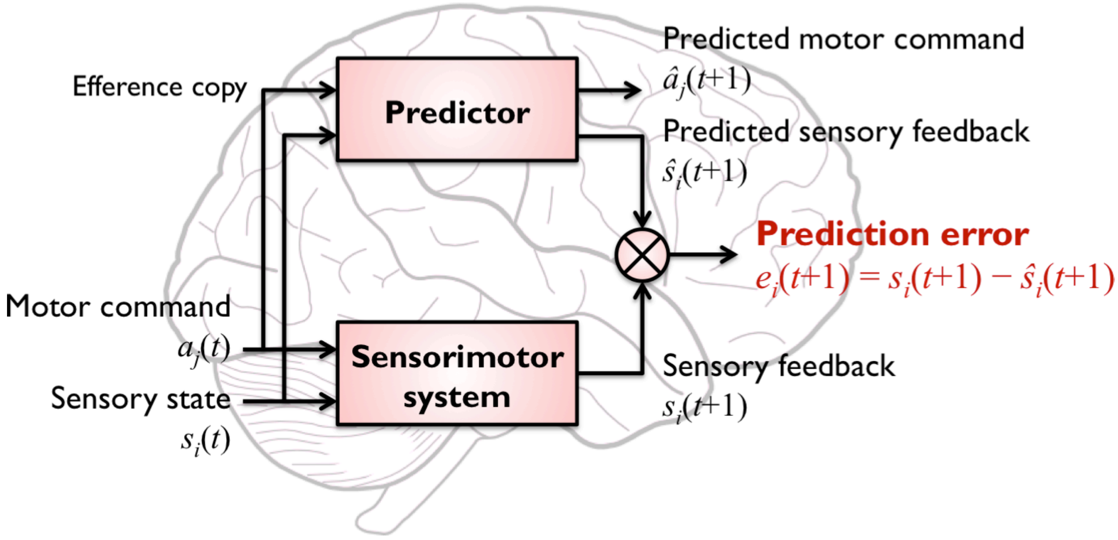

Figure 1:Predictive learning of sensorimotor signals (adapted from Nagai & Asada, 2015). A predictor (the top) learns to simulate temporal sequences of sensorimotor signals obtained by a sensorimotor system (the bottom). Infants first update the predictor by minimizing a prediction error while generating own actions. Infants then apply the predictor to recognize actions demonstrated by others. This is why self-experiences influence the understanding of others' actions.

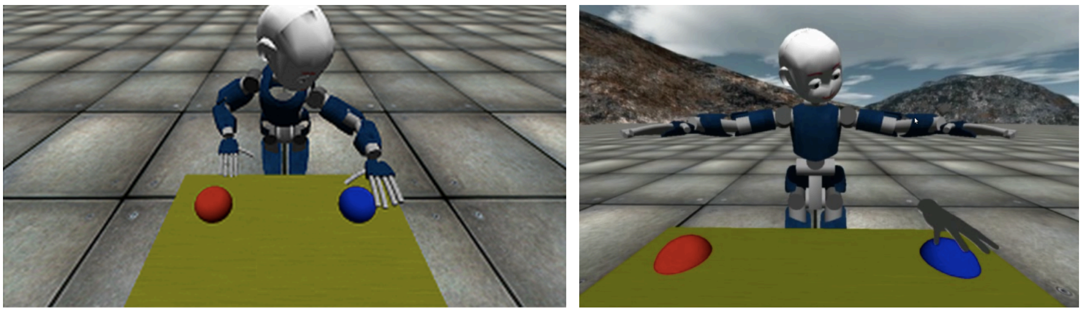

Figure 2: A robot experiment to examine how self-experiences of actions influence the understanding of others' actions (adapted from Baraglia et al., 2015). The left picture shows a robot reaching for an object, while the right shows the same robot observing others' hand reaching for the same object. The robot is equipped with a predictor, which learns to simulate the temporal sequences of sensorimotor signals. Because of a close link between the sensory and motor signals obtained in the predictor, motor experiences of the robot affect its perception of others' actions.